ANL-HEP-TR-85-123

ARGONNE NATIONAL LABORATORY

HIGH ENERGY PHYSICS DIVISION

QUARTERLY REPORT OF RESEARCH ACTIVITIES

July 1, 1985 — September 30, 1985

ARGONNE NATIONAL LABORATORY • UNIVERSITY OF CHICAGO

ARGONNE NATIONAL LABORATORY

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High Energy Physics Division Quarterly Report of Research Activities
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I. EXPERIMENTAL PROGRAM

A. Physics Results

1. HRS Physics

Two letters were published during the quarter: Measurement of the Topological Branching Fractions of the τ Lepton, Phys. Rev. Lett 55, 570 (1985); Neutral K*(890) and ρ° Meson Production in e^+e^- Annihilation at $\sqrt{s}$ = 29 GeV, Phys. Lett. 158B 519 (1985).

A careful study of the two reactions $e^+e^- \to \gamma\gamma$ and Bhabha scattering $e^+e^- \to e^+e^-$ has been completed The data samples, which are obtained from an integrated luminosity of 165 pb^{-1}, are 14880 events of the $\gamma\gamma$ final state and 84423 Bhabha scattering events. The data were selected in the central region of the detector ($|\cos\theta| < 0.55$) where the systematic errors can be controlled to better than 1%. This precision is a factor of two to three times better than has been achieved previously for these reactions. The results were compared to the predictions of QED to order α^3. The ratio of the cross sections, as compared to the same ratio calculated from QED and including the electroweak contribution to Bhabha scattering, is 1.007 ± 0.009 ± 0.008. Figure 1(a) shows the angular variation of the experimental ratio of the two cross sections compared to the QED prediction which is shown as the line. In Fig. 1(b) the $\gamma\gamma$ cross section is compared to the QED prediction (center line). The agreement is good. The upper and lower lines correspond to Λ_+ = 59 GeV and Λ_- = 59 GeV in the parametrization

$$\frac{d\sigma}{d\Omega}(e^+e^- \to \gamma\gamma)/(\frac{d\sigma}{d\Omega})_{QED} = 1 \pm \frac{s^2\sin^2\theta}{2\Lambda_\pm^4}$$

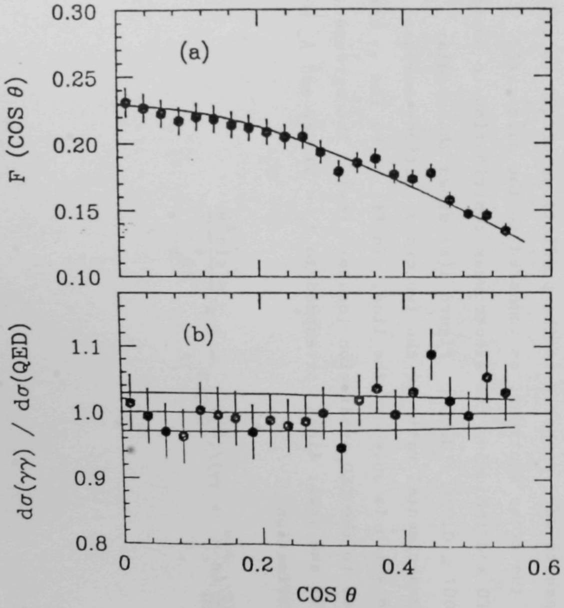

Fig. 1. (a) Direct comparison of the reactions $e^+e^- \to \gamma\gamma$ and $e^+e^- \to e^+e^-$ at a center-of-mass energy of 29 GeV. F(cosθ) is the ratio of the γ-pair differential cross section to Bhabha differential cross section, where the latter is folded at cosθ = 0. The curve shows the expectation of QED to order α^3 together with a small (∿ 1%) correction for electroweak effects. (b) Ratio of the observed-to-expected differential cross section for $e^+e^- \to \gamma\gamma$. The upper and lower curves, respectively, represent the lower limits (95% confidence level) for the QED cut-off parameters, $\Lambda_+ > 59$ GeV and $\Lambda_- > 59$ GeV.

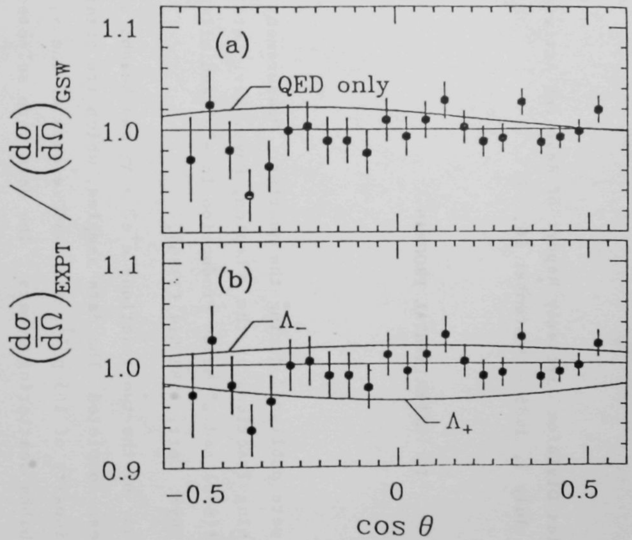

Fig. 2. (a) Ratio of the experimental Bhabha differential cross section to the expected GSW differential cross section at 29 GeV. The pure QED result (with $g_a^2 = g_v^2 = 0$) is shown for comparison. (b) The same data are compared to the 95% confidence lower bounds on the QED cut-off parameters (Λ).

The results of a similar study of the e^+e^- final state are shown in Fig. 2(a). In this case the predictions of the Glashow-Salam-Weinberg (GSW) model differs from pure QED. The data favor the GSW model (χ^2/N_D = 21.6/19) over pure QED (χ^2/N_D = 35.4/21). Standard model parameters of $g_a^2 = 0.46 \pm 0.14$ and $g_v^2 = 0.03 \pm 0.09$ are obtained that are in good agreement with the values $g_a^2 = 0.25$ and $g_v^2 = 0.004$ expected for $M_z = 93$ GeV and $\sin^2\theta_w = 0.217$. The 95% C.L. limits on the QED cut off parameters are $\Lambda_+ > 154$ GeV and $\Lambda_- > 250$ GeV and the curves on Fig. 1(b) correspond to these limits. A value of Λ = 200 GeV implies point-like scattering down to a distance of 10^{-16} cm.

An analysis of the three-jet events observed in a data sample corresponding to an integrated luminosity of 185 pb^{-1} has given new information on the charged particle multiplicities of gluon jets. A sample of 3965 three-jet events was selected using a jet-finding algorithm. The particle flow in these events is shown in Fig. 3(a) where the jets are ordered according to the angles between neighboring jets; jet 1 ($\phi = 0$) is defined as the jet opposite to the smallest angle and similarly, jet 3 is opposite to the largest angle. The curve shows the prediction of the Lund string model. Figure 4 shows the energy variation of the mean charged multiplicity for each jet in three energy bins. The line, which is a fit to the jet multiplicity determined from all e^+e^- annihilation (two-jet) data in this energy range, agrees well with this three-jet data. In particular there is no sign of a higher multiplicity for jet 3, even though this jet is enriched in gluon fragmentation.

This question has been studied in more detail by selecting a sample of symmetric three-jet events, shown in Fig. 3(b). In this case the jets are ordered on charged particle multiplicity, with jet 1 defined as the jet having the lowest multiplicity, and with $n_1 < n_2 < n_3$. An analysis of these $q\bar{q}g$ events gives $\langle n\rangle_g = 6.7\,^{+1.1}_{-2.1} \pm 1.0$ as compared to $\langle n\rangle_q = 5.2$ for jet energies of 9.7 GeV. The ratio $\langle n\rangle_g/\langle n\rangle_q$ is $1.29\,^{+0.21}_{-0.41} \pm 0.20$ which is significantly lower than the value of 9/4 naively expected from the ratio of the gluon-to-quark color charges.

(M. Derrick)

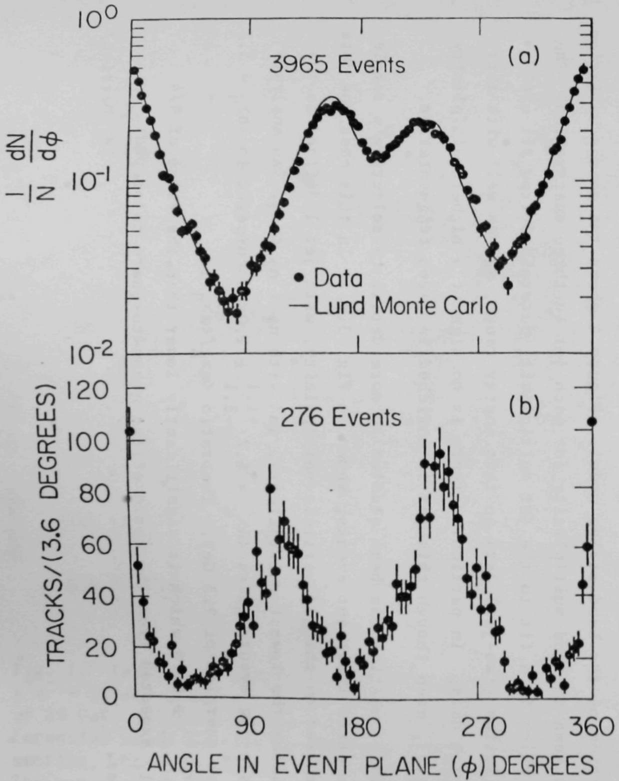

Fig. 3. (a) Particle flow on the event plane for the three-jet events with normicity $C_3 > 1.05$ after the angle ordering. (b) Particle flow on the event plane for the symmetric three-jet events with normicity $C_3 > 1.10$ after the multiplicity ordering. Jet 1 appears narrower than jets 2 and 3 since the angle is measured with respect to the jet 1 axis.

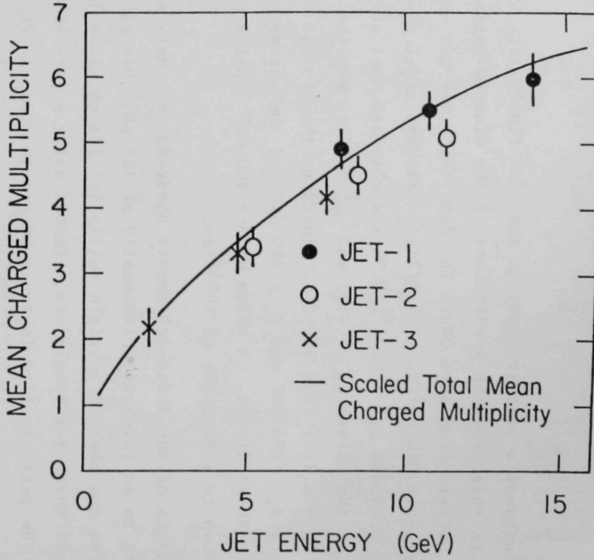

Fig. 4. Mean charged particle multiplicity for the data of Fig. 1(a) as a function of jet energy. The line shows the variation of the single jet multiplicity for $e^+e^- \to$ hadrons as a function of the jet energy ($\sqrt{s}/2$).

2. Effective Mass Spectrometer

We summarize some results from our analysis of inelastic proton-proton scattering in the dibaryon resonance region; a Physical Review article is in preparation. The reaction studied is $p\uparrow p \to pn\pi^+$ in the momentum range from 1 GeV/c to 2 GeV/c and the data were taken using the Effective Mass Spectrometer and the polarized proton beam from the ZGS. The most important unresolved question on dibaryons concerns the presence or absence of Breit-Wigner phase behavior for the process $\Delta N \to \Delta N$. This is because a $pp \leftrightarrow \Delta N$ coupled-channel description requires three parameters for each wave, namely the $pp \leftrightarrow \Delta N$ cross section and the phase shifts, δ_{pp} and $\delta_{\Delta N}$, which characterize $pp \to pp$ and $\Delta N \to \Delta N$ transition respectively; the phase shifts, $\delta_{\Delta N}$, have so far not been measured. These phase shifts are particularly important for interpretation of the low energy data, because the dibaryon resonances show up as only tiny loops in the pp elastic Argand plots; if the resonances were coupled-channel Breit-Wigners, then they would appear as much larger loops in the $\Delta N \to \Delta N$ Argand plots since $\Gamma_{\Delta N} >> \Gamma_{pp}$, and would give rise to ~ 180° counterclockwise rotations in $pp \to \Delta N$. Of course, if they were not Breit-Wigner resonances but merely coupled-channel threshold effects, they would not be expected to cause Breit-Wigner phase behavior.

With reasonable constraints on the behavior of the high partial waves and on the relative partial-wave cross sections, fairly stable solutions are obtained for the dominant $pp \to \Delta N$ waves. The Argand plots for these leading waves (involving S or P waves in the ΔN final states) are shown in Fig. 5. The "resonance" waves ($^1D_2$ and $^3F_3$) and also the smaller background waves ($^3P_1$, $^3P_2$, $^3F_2$) all rotate clockwise with increasing energy. We cannot get good fits if, say, the $^1D_2$ wave is forced to have a counterclockwise phase variation. The relative phases are such that, if the $^1D_2$ wave were forced to exhibit Breit-Wigner behavior, then all the other waves would have to show similar phase behavior.

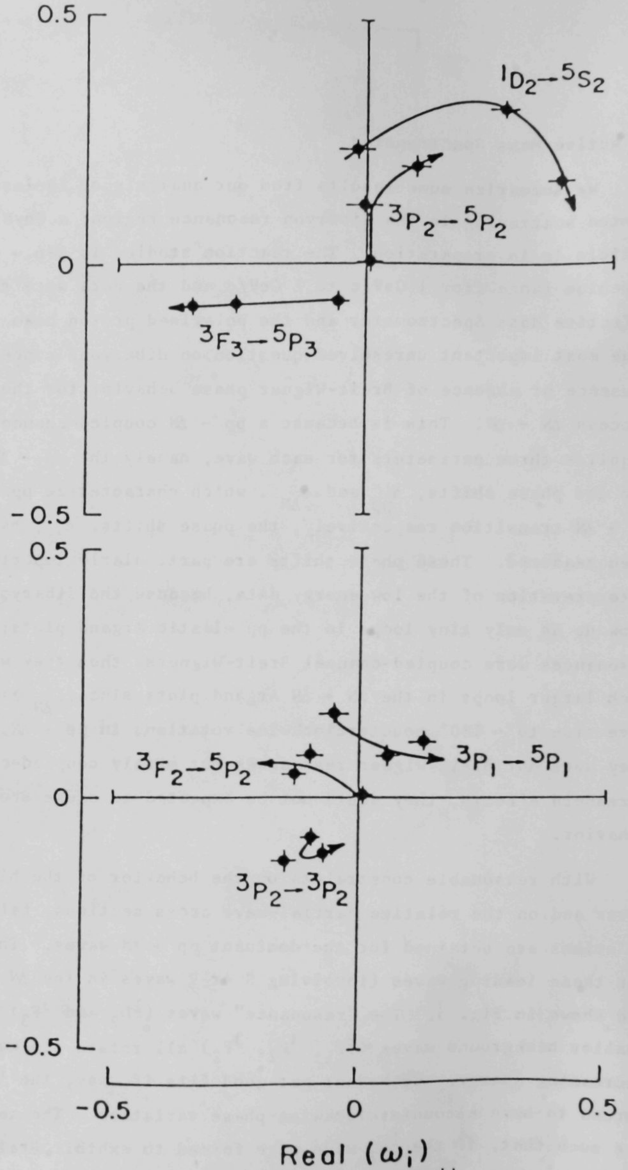

Fig. 5. Argand plots for the larger waves in $pp \rightarrow \Delta^{++}n$. Crosses indicate amplitudes at 1.2, 1.5, and 1.7 GeV/c, and arrows indicate sense of rotation at 1.7 GeV/c; curves indicate Argand trajectories obtained by fitting interpolated data at intermediate momenta, in order to arrive at continuous solutions. The unitarity limit corresponds to $|\omega_i| = 0.5$.

The clockwise rotation of the leading waves is not totally unexpected. In the elastic channel, all of the waves which exhibit large phase shifts ($^1S_0$, $^3P_0$, and $^3P_1$ in pp, and $^3S_1$ in pn) rotate clockwise. The resonant waves, $^1D_2$ and $^3F_3$, rotate counterclockwise in pp $\rightarrow$ pp but their phase shifts rotate by only a few degrees. Thus, it may not be surprising that the large waves in $\Delta N \rightarrow \Delta N$ ($^5S_2$, $^5P_1$, $^3P_1$, $^5P_2$, and $^3P_2$) all rotate clockwise; via unitarity, the overall clockwise rotation of the sum, $\delta_{pp} + \delta_{\Delta N}$, gives a clockwise phase variation in the pp $\rightarrow$ ΔN waves.

The analysis does not favor coupled-channel Breit-Wigner descriptions of the dibaryons, as might be expected for exotic hidden color interpretations; it suggests more pedestrian interpretation in terms of threshold effects or virtual bound states coming, for example, from ordinary meson-exchange forces. (A. B. Wicklund)

3. Fermilab Jet Experiment

Using the events triggered with two high P_T jets produced in pion-proton and proton-proton interactions at 200 GeV, we have made a detailed search for the higher-twist hard-scattering process proposed by Berger and Brodsky. In this process, both of the quarks in the pion would participate in the hard scattering, resulting in a high-p_T pion jet (balanced by a recoiling high-p_T jet) plus a target jet but no "beam jet". Hence, these "dijet" events would be characterized by little or no residual energy near the forward beam axis. They would be expected to occur in πp but not in pp collisions.

Software cuts chosen to select dijet events were imposed. Then a variable X_b was defined as the ratio of the forward energy flow (the beam calorimeter energy, corresponding to energy at < 25° c.m.) to the total energy. The distribution in X_b was studied as a function of the planarity, with results as shown in Fig. 6. At extremely high planarities (> 0.95), Fig. 6c shows a shoulder or possibly a bump in the πp distribution at very low X_B, whereas no such structure is seen in the

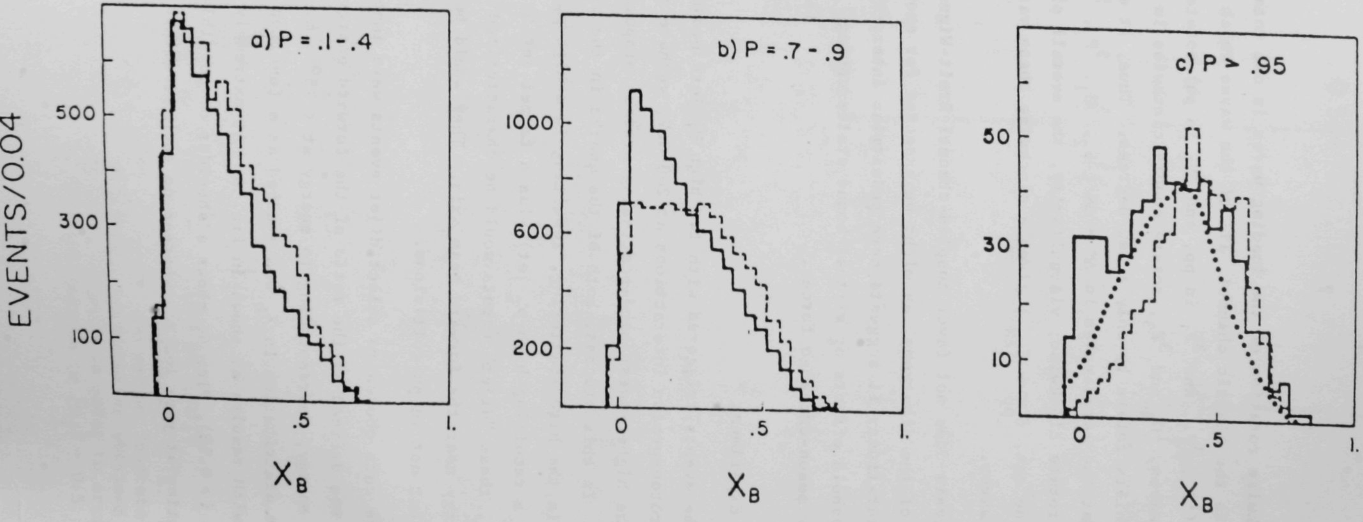

Fig. 6. Distribution of x_B, the ratio of the forward energy flow to the total observed energy, in three ranges of planarity, for πp events (full curves) and for pp events (dashed curves). The two curves in each plot have been normalized to the same flux. The dotted curve in c) is the Monte Carlo prediction for πp events in the absence of higher-twist effects.

pp case. We conclude that there is definite evidence for a higher twist effect, since we cannot explain the observed structure in terms of a smoothly falling pion structure function as $X \to 1$.

A paper describing this analysis has been submitted to Physical Review Letters (Argonne, Fermilab, Michigan, Penn, Rice, Wisconsin collaboration). (T. Fields)

B. Experiments Taking Data

1. HRS Operations

The PEP storage ring did not operate during this quarter. One big cee of the magnet pole tips was removed to repair a wire in the end cap PWC system. A corroded capacitor was replaced and the system brought back to full operational state.

Processing of all of the data taken during FY1985 was completed and physics analyses based on the full ~ 255 pb^{-1} data sample are under way.

The SLAC director was advised of the decision taken by the collaboration not to propose continued HRS data taking after the PEP shutdown in March 1986. (M. Derrick)

2. Spin Physics at LAMPF

Activity this quarter focussed on data taking for measurement of the np elastic scattering spin parameter "C_{SS}" at $T_{lab,n}$ = 500, 650 and 800 MeV. The polarized target had to be rotated about 53° from pure S-type in order to obtain acceptance for the proton over the range θ_{lab} ~ 0-50° and avoid the beam neutrons or recoil protons hitting the coils of the polarized target magnet. Pure values of C_{SS} will be extracted from the measurements using previous results on C_{LL} and C_{SL} at these angles. In addition to polarized target data, measurements were made with a carbon target to obtain the shape of the background contribution.

Some effort was also devoted to data analysis tasks;

A) A paper describing the 1m x 3m drift chamber is nearing completion. Some data from this year have been analyzed to compare the performance of delay line readout electronics to LRS 4290 system electronics with individual amplifiers on each sense wire.

B) The calibration procedure for the front drift chamber (built by Texas A&M University) has been changed. A lookup table for the time differences from the ends of the delay lines on this chamber is being prepared. Shorts in the delay line and missing wires in the chamber have caused problems in the past.

C) Additional work on calibrating the delay lines for the rear chambers has resulted in final values for 3 of the 4 constants for each delay line for the 1984 and 1985 runs. All constants have been previously found for the 1983 data.

D) The magnetic field of the spectrometer magnet was measured in 1983 and values of $\int B d\ell$ over the magnet aperture were obtained. Recent indications from the elastic scattering data show problems over about 20% of the spectrometer acceptance and the magnetic field measurements will need to be extended to regions not previously mapped. These are planned for early 1986.

E) Analysis of data collected with the spectrometer at θ_{lab} = 0-25° have shown a signal at small angles for the np → dπ° reaction. Plans are being made to obtain C_{LL}, C_{LS} and C_{SS} for this reaction from our data tapes. Other data on C_{LL} and C_{SL} exist for the pp → $d\pi^+$ reaction, but none are presently available for C_{SS} at the higher LAMPF energies (650 and 800 MeV).

Three new proposals were accepted by the LAMPF Program Advisory Committee (PAC) in August. In 1986, tests will be made to optimize measurements of $\Delta\sigma_L$(np) and $\Delta\sigma_T$(np), absolute neutron counter efficiencies will be measured, and the np elastic scattering spin parameter C_{NN} will be obtained at 800 MeV. Also, tests will be performed for the new beam buncher which is to be installed before the runs in 1986. In 1987, measurements of $\Delta\sigma_L$(np) or $\Delta\sigma_T$(np) will be made at five energies.

In addition, the LAMPF PAC encouraged work on new target materials to provide polarized nuclei for elastic scattering experiments with pions and polarized protons. Argonne expertise with polarized targets, and the availability of apparatus to test new materials, may be very important for the success of these new experiments. A proposal to test phenomenological predictions for nucleon scattering from polarized ^{13}C has been submitted. (H. Spinka)

3. Soudan 1

The Soudan 1 detector continued to operate for cosmic ray physics and ran well throughout the quarter. The WWVB clock, which can provide the absolute time to 1 msec accuracy, was used to check the less accurate clocks which were used previously on Soudan 1. The new clock was installed last quarter, and will make it possible to search for short-period modulation of cosmic rays, for example from fast pulsar sources. Soudan 1 cosmic ray results were presented by Argonne physicists at several summer conferences during the quarter. (D. Ayres)

C. Experiments in Preparation Phase

1. Collider Detector at Fermilab (CDF)

With the completion of module calibration in the NW test beam, systematic studies of calorimeter performance continued to the end of August, which marked the end of fixed target running. The remaining important areas to be studied involve boundaries with other calorimetery and the response below 10 GeV.

Agreement to fund the fabrication of chambers for tagging energy at azimuthal cracks was reached and procurement of parts started. A preliminary study of the background level from the uranium radiator was completed; the background is large but does not preclude the use of uranium.

The main activity was in preparation for the colliding beam run

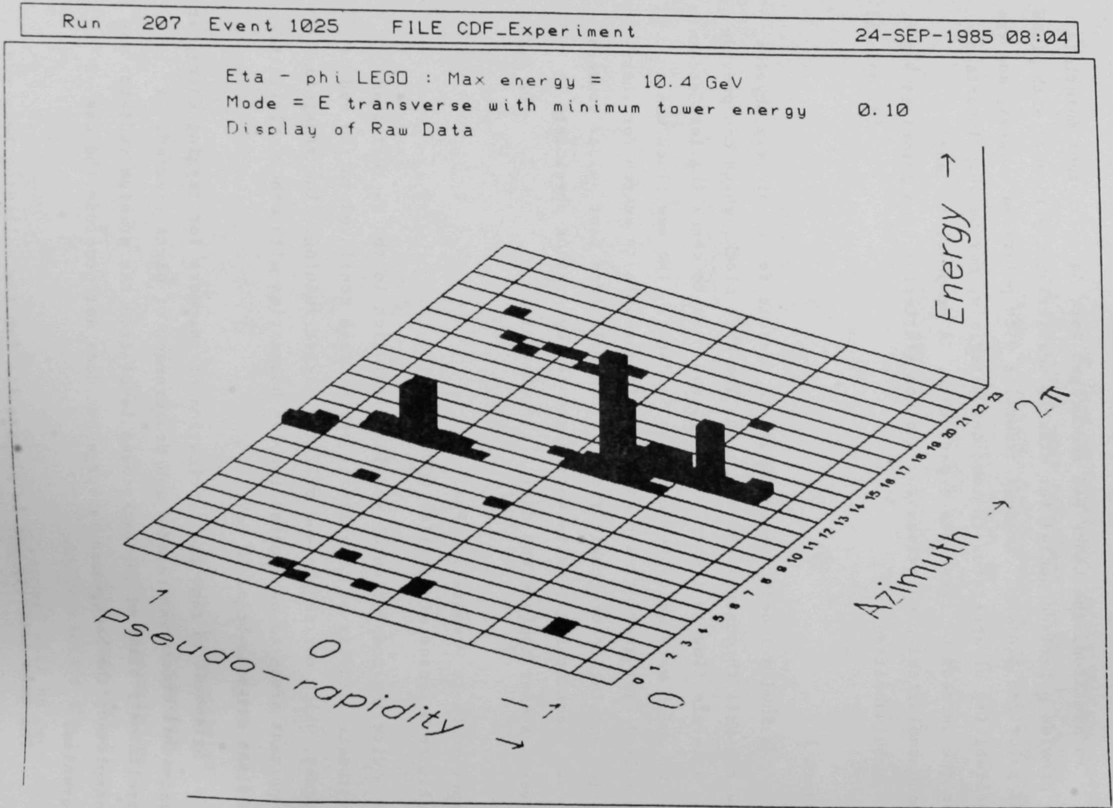
Run 207 Event 1025 FILE CDF_Experiment
24-SEP-1985 08:04
Eta - phi LEGO : Max energy = 10.4 GeV
Mode = E transverse with minimum tower energy 0.10
Display of Raw Data
Energy →
Azimuth →
0
2π
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1
0
-1
Pseudo-rapidity →

Figure 7.

scheduled for September. All of the central and wall scintillator calorimetry was made operational. Half of the hadron calorimeter photomultipliers were equipped with TDC's as well as ADC's. A full complement of eight vertex chamber TPC modules was installed with readout for more than 90% of the 3072 wire channels. The 32 forward and backward beam-beam trigger counters were installed. Samples of 14 modules of central muon chambers, two central strip chambers and a prototype forward silicon spectrometer were installed. Particular attention was paid to monitoring radiation levels to avoid radiation damage to plastic scintillator.

Argonne effort was particularly directed at checking out the phototubes and the front end RABBIT electronics, and at installing a simple calibration system. Work was also done on software for readout and calibration, as well as for monitoring performance of the whole detector. The effort peaked on September 9 when the detector was rolled in.

About ten days later, after several days of machine physics with no access to the detector due to radiation interlocks, access became available and it was found that no significant repairs were needed. Cosmic ray and single beam studies were done and the level-one trigger system was brought up and debugged. A single beam background event calorimeter display is shown in Figure 7. (L. Nodulman)

2. Nucleon Decay

Preparation of the new underground laboratory at the Soudan mine proceeded on schedule during the quarter, with the completion of the wall shotcreting and the pouring of most of the concrete floor. A survey of the cavity dimensions revealed a few places near the top corners which require trimming to allow adequate space for the active shield, but this should not cause any significant delay in the cavity completion. Figure 8 is a recent photograph of the new cavity.

Fig. 8. Photograph of the new Soudan 2 underground laboratory. The facility is located 2400 ft underground in Tower-Soudan State Park in northeastern Minnesota. Only about half of the 45 ft by 235 ft by 38 ft high cavity is shown. At the time of the photo, shotcreting of the cavity walls was still in progress, and the concrete floor had not yet been started.

Argonne engineers worked closely with the Soudan mine engineer and the excavation contractor on various aspects of the cavity outfitting. The final dimensions of the steel support structure for the main detector, shield, and crane were agreed upon following the cavity survey. Detailing of the active shield support hardware and the final shield layout proceeded in parallel with the steelwork specification, and was nearly completed at the end of the quarter. The design of the electrical power system was finalized, and ordering of components started. This system will supply 80 kVA of quiet power for the electronics and computer, and 60 kVA for other uses; isolated grounds and shielded transformers will provide an electrically quiet environment for the main drift chamber electronics.

The details of the air-handling and fire-protection systems were also finalized. Fans and ductwork to the rear of the active-shield enclosure will exchange the air in the cavity every hour. The fans and other electrical devices will be turned off in the event of a smoke detector alarm, and a water sprinkler system will provide back-up fire protection. The counting house specifications were also finalized, and the bid package for this prefabricated office-type enclosure was sent out during the quarter. Work on all of these systems will be completed by early 1986, when beneficial occupancy of the new underground laboratory will occur. Finally, hiring of the mine-site support staff was started during the quarter, in preparation for the many installation activities which will begin as soon as the cavity outfitting is completed.

Activities of the Argonne group during the quarter focussed on the production of 5-ton calorimeter modules and readout electronics. The assembly of Module #2 was completed following a concentrated effort to eliminate the gas-poisoning and high-voltage problems that were encountered in Module #1. While careful testing of all components was completely effective in eliminating the gas contamination found in the first module, the screening of bandolier for high-voltage faults was only partially successful: at the initial turnon of Module #2, 80% of the drift structure operated well at the full 10 kV drift voltage, but a subsequent breakdown forced a reduction to 5 kV, where the module has operated satisfactorily for over two months.

Many resources were focussed on the high voltage problem during this period, and by the end of the quarter a plan for dealing with it had been developed. In the short term, high voltage faults will be bypassed rather than repaired, yielding modules with a few of their 256 layers disabled. Enough modules will be produced to accumulate cosmic-ray performance statistics and to begin operation of modules in the mine. In the longer term, the high voltage insulation will be modified to reduce the fault rate to a lower level.

The study of Module #2 with cosmic rays was facilitated by the replacement of the 128 channels of prototype front-end electronics by 320 channels (half of the total required) of production front ends, whose fabrication was completed at Oxford last quarter. Installation of the final 320 channels on Module #2 was in progress at the end of the quarter. The new electronics allowed the performance of Module #2 to be studied in much more detail than was possible for Module #1. The track-reconstruction software needed for studying drifting efficiency at the tube level was under intensive development during the quarter and made good use of cosmic ray data from Module #2. Initial results indicate satisfactory performance of the new rectangular cathode pads used for the first time in Module #2, and reasonable drifting in the calorimeter stack. Experience with the first 320 channels of front-end electronics led to a number of minor changes to the preamp hybrid circuit design. The contract for fabrication of these hybrids was awarded to a U.S. manufacturer during the quarter, and production of sample units will begin soon.

The assembly and testing of the 1300 channels of ADC electronics for the U.S. and U.K. module factory test facilities was nearly completed during the quarter, and components were shipped to both the Rutherford module factory and to the University of Minnesota for online software development. Testing of the remainder of the ADC cards for the U.K.

system and of the trigger gate array logic chips was still in progress at the end of the quarter. Procurement of components for half of the ADC electronics needed for Soudan 2 itself is now complete, and assembly and testing of this 3100 channel system is scheduled to begin soon. Fabrication of the trigger and calibration electronics was started with testing of the hardware and associated software scheduled for next quarter.

The production of corrugated steel for U.S. modules proceeded on schedule during the quarter. Tooling for steel fabrication in the Argonne shops was upgraded and materials were received for the 12-module production run which will take place next quarter. Tooling for production of steel for 12 more modules by the U.S. commercial steel fabricator was also completed, and sample sheets for evaluation are expected to be delivered soon. (D. Ayres)

3. Fermilab Polarized Beam

While construction of the experimental hall at Fermilab proceeded rapidly, there was progress on many projects at Argonne for both the beamline facility and the experiment.

A new round of studies to optimize the tagging hodoscopes and associated fast memory look-up logic was begun. For this study, the beam Monte Carlo, based on the standard decay turtle program, was modified at Argonne so that a data summary tape can be written and much more complex correlations can be studied efficiently. This study will proceed in cooperation with Northwestern University where the tagging counters will be constructed.

The required field uniformity in the prototype magnet for the spin precession snake was achieved. Based on this success, the drawings for parts to be constructed by Fermilab were finalized.

The field mapping work was done at the IPNS test beam area, with pole modifications and construction of a quick-change shim holding jig being done in the Argonne central shops. The field mapping equipment was designed and constructed in the HEP Division.

Software to derive a multipole expansion from minimal measurements of the field integral was developed.

Also during this quarter, Argonne contracted with an outside machine shop for the rework of the magnet cores and machining was begun.

After testing minimal configurations of two possible MWPC readin systems, one commercial system was chosen and enough components ordered to instrument at least one chamber. These will be used temporarily in an experiment at LAMPF in order to gain experience with the system.

Development of the data acquisition system continued at Argonne. Questions of overall software control which were raised at the E-704 data acquisition meetings were addressed. (D. Underwood)

4. Fractional Charge Search

Resolution of integral electric charges on ethylene glycol drops for an analyzing voltage of 20 kV has now been successfully demonstrated. Figure 9 shows a distribution of apparent charges which corresponds to an upper limit for the concentration of one third fractional charges of 1 per 15 μg (in the ethylene glycol sample liquid). Data which will establish more stringent limits are being analyzed. (J. Van Polen)

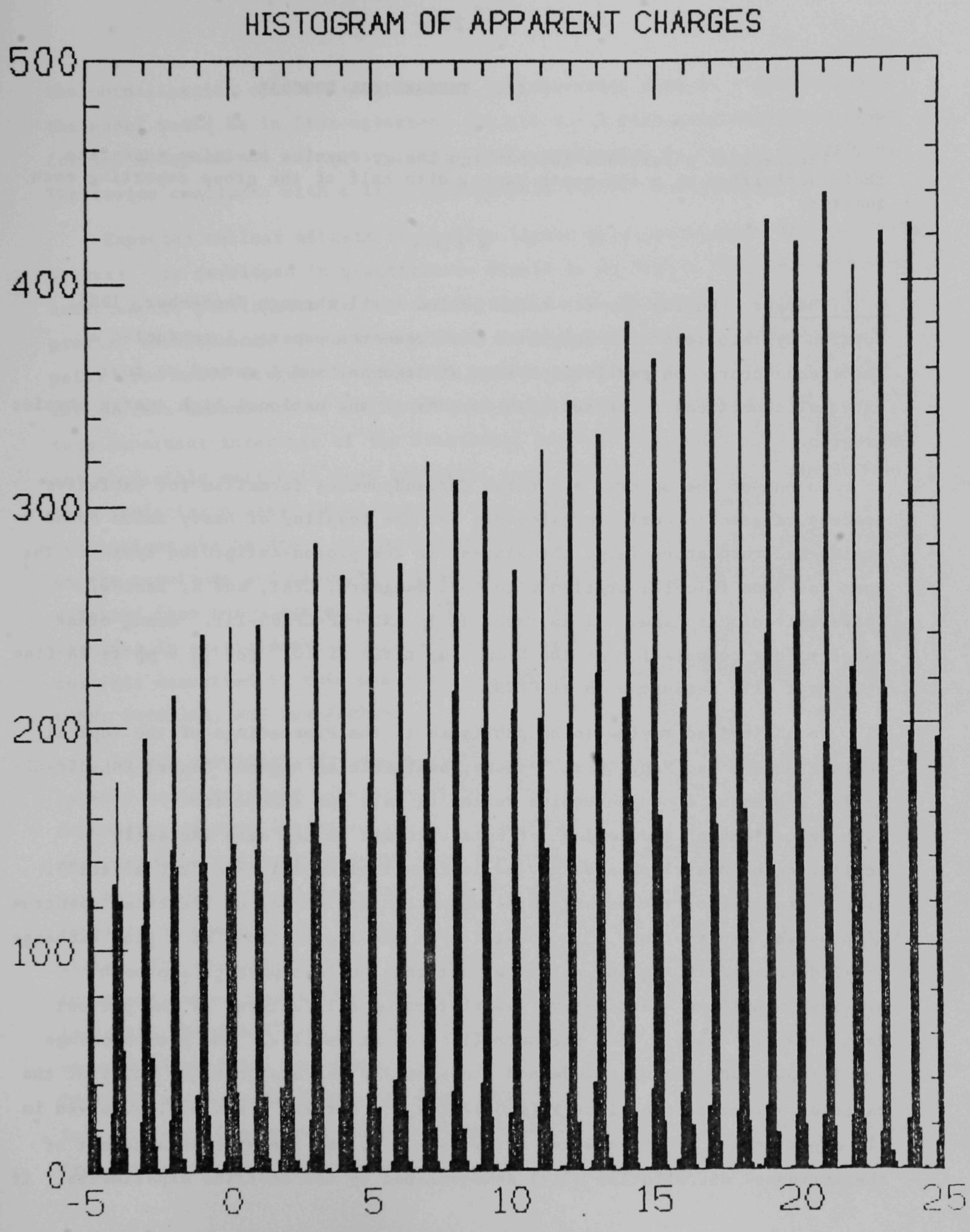

Fig. 9. Histogram of apparent charges reconstructed from quark search data representing over 30,000 droplets. Rejected droplets not included here. Unit on horizontal scale is "electron charges".

II. THEORETICAL PROGRAM

Theoretical physicists in the High Energy Physics Division summarize their activities on a six-month basis, with half of the group reporting each quarter.

* * * *

E. L. Berger. During the six month period April through September, 1985, covered by this report, I completed five research papers, I conducted a Chautauqua course on particle physics at Argonne, and I served on four external committees concerned with aspects of the national high energy physics program.

In one of the papers, a Quantum Chromodynamics formalism for exclusive process is used to derive predictions for the coupling of heavy onium bound states and resonances (e.g. chi states) to the proton-antiproton system. The work was done in collaboration with Poul Damgaard, CERN, and K. Tsokos, University of Maryland. It is reported in ANL-HEP-CP-85-111. Among other results, our computation of the branching ratio of 10^{-4} for $\chi_2 \to p\bar{p}$ is in fine agreement with measurements at CERN.

In an invited review to be published in the Proceedings of the Topical Seminar on Few and Many Quark Systems, available as Argonne report ANL-HEP-CP-85-70, I present a comprehensive review of data and theoretical interpretations of A dependent effects observed in the deep inelastic scattering of neutrinos and charged leptons from nuclei (the "EMC effect"). After a summary of the experimental situation and survey of the broad spectrum of proposed explanations, I concentrate on the implications of a pion exchange model developed at Argonne. I show that this nuclear physics approach provides a unified quantitative description of all features of the present data except, possibly, for the normalization at small x. The pion exchange model reproduces the magnitude and shape of the depression below unity of the ratio of structure functions $F_2^A(x,Q^2)/F_2^D(x,Q^2)$ for $0.2 < x < 0.6$, observed in all experiments, its rise above unity as $x \to 1$, and the weak enhancement of the antiquark distribution $\bar{q}^A(x)$ demonstrated by the neutrino experiments. If the normalization of the European Muon Collaboration data is reduced by 5%, the model would be in fine agreement for all x. I also provide expectations for the A dependence of massive lepton pair production in hadron collisions. The review concludes with a list of desirable future experiments.

Expected nuclear effects in massive lepton pair production, the Drell-Yan process, are developed in quantitative detail in my report ANL-HEP-PR-85-102 accepted for publication in Nuclear Physics B. In this paper, I show that precise measurements of nuclear effects in the production of massive lepton pairs from heavy targets by pion and proton beams would extend knowledge of the nuclear dependence of antiquark and quark structure functions of nucleons into important intervals of the fractional longitudinal momentum variable x_{Bj} not accessible easily in deep inelastic scattering. Moreover, I demonstrate that isolating nuclear dependence is also essential before definite conclusions can be drawn on the behavior of the pion structure function, and on the magnitude and kinematic variation of the perturbative QCD K factor obtained from heavy target data. Thus, studies of A dependence are of basic interest in particle physics as well as for models of nuclear structure. The analysis described in this paper has stimulated interest in new experiments at CERN, Fermilab, and Los Alamos.

In the remaining two papers, Fritz Coester and I treat theoretical aspects not previously addressed of our pion exchange model for the nuclear dependence of deep inelastic lepton scattering. We provide a detailed derivation of the fact that the deep inelastic structure function of a nucleus may be expressed directly in terms of the empirical structure functions of the constituent nucleons and mesons and the wave function of the nuclear bound state. The assumptions made are specified and discussed. We resolve important issues about which confusion has existed in the literature, including "on-shell" versus "off-shell" ambiguities, the derivation of momentum densities, and the role of momentum balance. These papers, ANL-HEP-CP-85-23 and ANL-HEP-CP-85-103, will appear in the Proceedings of the International Conference on Hadronic Probes and Nuclear Interactions, and the Proceedings of the Santa Barbara Workshop on Nuclear Chromodynamics.

In collaboration with Michael Harris of Argonne's Division of Educational Programs, I organized and directed a Chautauqua Short course held at Argonne April 17-19: "Elementary Particle Physics: Current Status and Perspectives". The course was attended by 97 enthusiastic college and university teachers of the natural sciences from 21 states and by Argonne staff from various basic research divisions. Letters received since testify to the success of the course of conveying the excitement of particle physics, the progress made during the past decade, the hopes for the future, including the SSC, to individuals who play a significant role in the educational process. Chautauqua short courses are an annual series of forums in which scientists meet intensively with undergraduate college teachers of science for several days. This was the first Chautauqua course on particle physics.

Contributions to the national high energy program during this period included my service on a High Energy Physics Advisory Panel (HEPAP) Working Group on Fixed Target Facilities in May, in preparation for the HEPAP summer meeting; as a consultant for the Department of Energy Review of the High Energy Physics Program at Brookhaven National Laboratory in June, 1985; as a consultant for the Department of Energy Review of the High Energy Physics Program at the Stanford Linear Accelerator Center in July, 1985; and as a member of the Steering Committee, Santa Barbara Institute for Theoretical Science Workshop on Nuclear Chromodynamics: Quarks and Gluons in Particles Nuclei, 1985.

* * * *

G. Bodwin. My work during the past six months has involved quantum electrodynamics bound state theory, perturbative quantum chromodynamics, phenomenology of hadron-hadron collisions, and lattice gauge theory. In addition, I have spent some time studying gravitational anomalies in quantum field theory.

With collaborator Donald R. Yennie (Cornell), I have begun a calculation of the $O(\alpha^2)$ recoil contribution to the hydrogen hyperfine splitting that is due to the proton's anomalous magnetic moment. This contribution accounts for about half of the theoretical uncertainty in the hyperfine splitting-- the remainder being due primarily to proton polarizability effects. Thus, the determination of this unknown contribution will allow one to put stronger constraints on the theory of the proton's structure. Our calculation is based on the new bound state formalism developed by Yennie, Miguel Gregorio (University of Rio de Janeiro) and my self. To date we have succeeded in evaluating the term proportional to ln α^{-1}, which gives the bulk of the contribution. The evaluation of the associated constant term is in progress. We have discovered an important simplification in the proton Dirac algebra that leads us to conclude that all of the required integrals are of a two loop type that we have evaluated previously in connection with the muonium hyperfine splitting.

Stanley Brodsky (SLAC), G. Peter Lepage (Cornell), and I are involved in an ongoing collaboration aimed at understanding the phenomenology of nuclear effects in hadronic processes. For the case of Drell-Yan production, we have made predictions as to the impact of initial state interactions and the EMC effect on the lepton pair transverse momentum distribution and have discussed the limits of validity of factorization in the case of a nuclear target. We are now in the process of writing a complete exposition of our analysis.

For a number of years a controversy has existed regarding the issue of fermion doubling in the so-called SLAC version of lattice field theory. Eve Kovacs (Argonne) and I are attempting to provide a definitive resolution of this controversy by studying the lattice Schwinger model (2-d quantum electrodynamics). In the continuum, the theory is completely soluble; preliminary investigations lead us to believe that this is also the case on the lattice. We plan to calculate exactly the mass of the lowest lying vector state and the axial vector anomaly--both of which are sensitive to the presence of fermion doubling. A comparison with the continuum results for these quantities should then provide a test of the validity of the SLAC approach to fermions on the lattice.

Eve Kovacs and I have also begun investigating the possibility of measuring the dielectric properties of the QCD vacuum via lattice Monte Carlo techniques. This work is based on the picture (espoused by S. Adler, C. Callan, R. Dashen, and D. Gross, among others) that the confinement property of the QCD vacuum can be understood by assuming that it behaves like a paramagnetic dielectric medium. We plan to carry out a part of this calculation on the CRAY-XMP at MFECC.

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M. Grady. My research for the past two years has been in the field of lattice gauge theory. My interest in this field developed out of an earlier interest in the dynamical breaking of chiral symmetries and in the mathematical analogues between field theory and equilibrium statistical mechanics. Numerical lattice simulations can provide valuable information concerning dynamical and non-perturbative phenomena which occur in strongly coupled theories such as Quantum Chromodynamics (QCD). To date these theories have not yielded much to analytical treatment. Not only can lattice simulations give valuable quantitative information now, but one might also hope that information and insight gleaned from the lattice might also help in developing more powerful analytical techniques. What most seems to be lacking is a thorough understanding of the QCD vacuum, in particular, how the presence of a particle condensate, such as the chiral condensate, affects the propagation and interactions of particles. My work aims at further elucidating these topics.

Recently, I have concentrated on improving the state of the art in lattice fermion simulations; current techniques are only barely able to tackle the more complicated physics questions, even when given a tremendous amount of computing resources. I describe in detail two of my recent findings.

1) New Fermion Monte Carlo Algorithm

In order to investigate dynamical chiral symmetry breaking on the lattice, it is essential to have a numerical algorithm which can simulate light fermions. Most work in lattice gauge theory to date has been done with pure gauge theory, because the methods available to treat fermions require hundreds of times more computer time than do standard methods for bosons, to achieve comparable statistics. The popular pseudo-fermion method of Fucito, Marinari, Parisi, and Rebbi also suffers from systematic errors which are difficult to estimate. I have developed a new method which appears, at least in two-dimensional systems, to alleviate most of the shortcomings of the other algorithms in use. In the spinless Schwinger model, the new algorithm with fermions runs only a factor of 2.5 slower than the corresponding pure gauge theory algorithm and produces gauge configurations of comparable quality. The results agree with those produced by an algorithm which computes the fermion determinant exactly at each update, within statistical errors which are about 5% of the fermionic effect on the system. There is also no detectable dependence on the hit size, which is the maximum amount that the new gauge field is allowed to differ from the old one in an update. This is in stark contrast to the pseudo-fermion method which has a large hit size dependence. The lack of an observable hit size dependence suggests that the method has no systematic error, since one can show, as with the pseudo-fermion technique, that the method is correct in the limit of small hit sizes. At the very least any systematic error would have to be very small, at the level of a few percent in the above example even at the maximum hit size. I have found a reasonable basis by which one can show that the method is free of systematic error, through relating it to a boson Monte Carlo for a system of gauge fields and bosons with the same interactions as the gauge/fermion system. However, this is not yet at the level of a rigorous proof. The basic idea is to equate the probability of transition from a gauge configuration A to a new configuration A' in the gauge/fermion system to the transposed probability in the corresponding gauge/boson system, i.e. the probability of transition from A' to A in that system. Transposing the transition probability matrix in the Monte Carlo simulation results in an equilibrium distribution in which all of the probabilities are simply inverted. This is exactly what is needed to produce the desired probabilities for the gauge/fermion system as these are proportional to det(O(A)) whereas those in the gauge/boson system are proportional to $1/\det(O(A))$, where $O(A)$ is the interaction operator in the Lagrangian.

In more complicated systems, the algorithm will become slower, however it appears that it will become no worse than 20-30 times slower than the pure gauge theory simulation in a non-abelian four-dimensional theory. In addition to the spinless Schwinger model, I have also tested the method successfully on the Schwinger model with Kogut-Susskind fermions, however here there have been a few surprises, which I describe in the next paragraph. I am currently preparing to test the method on a simple four-dimensional problem after which I will apply it to a QCD-like theory.

2) Species Doubling

It has been proven by Nielsen and Ninomiya that any lattice fermion formulation which respects chiral symmetry, locality, and hermiticity necessarily has more than one species which survives in the continuum limit. The Wilson formulation avoids this at the expense of breaking chiral symmetry, but this makes it very difficult to study spontaneous chiral symmetry breaking since the symmetry is already strongly broken explicitly. The Kogut-Susskind staggered formulation reduces the amount of species multiplication to two species in two dimensions and four in four dimensions (in the Euclidean Lagrangian formulation). The multiple species have been interpreted as different flavors in the continuum limit. However, having the lattice simulations restricted to multiples of four flavors in four-dimensional theories is not entirely satisfactory. Through studying the lattice Schwinger model with Kogut-Susskind fermions I have found a possible solution to this problem.

I find that for relatively large fermion masses, simulations agree well with an exact algorithm for two fermion flavors, but for small masses they don't. Rather, they agree very well with the exact algorithm configured for one flavor (the exact algorithm can treat any number of flavors by raising the determinant to an appropriate power but its use is limited to a small lattice). Extrapolations to the massless model also agree with the one flavor continuum analytic solution. The species doubling can be viewed as an unwanted discrete symmetry on the lattice, which is related to the interchange of sublattices. I have found evidence that for small fermion masses this discrete symmetry is spontaneously broken. The evidence comes from observation of an order parameter sensitive to the symmetry as small amounts of explicit symmetry breaking are applied and as the lattice size is changed. In principle the same techniques could be applied to the exact algorithm, however the limitation to small lattice sizes (6x6) makes this difficult since spontaneous symmetry breaking is essentially a long distance phenomenon. In the absence of explicit symmetry breaking the exact algorithm sums over both degenerate vacua and counts both flavors. If the symmetry is spontaneously broken, then, in the limit of infinite lattice size, only one-half of the fermion modes can be excited, since the other half belong to a subspace of configurations which cannot be reached. In canonical language the Hilbert space is bifurcated - the theory is defined over one or the other subspaces, but not both together. Thus one can obtain a single effective flavor, if the system should prefer the broken symmetry solution. It is known that low mass fermions suppress vortex configurations in two dimensions and instantons in four dimensions. When the effective number of flavors is reduced this suppression factor becomes much smaller, liberating such gauge configurations. If the increased entropy of the gauge fields more than counteracts the decrease in entropy of the fermions under symmetry breaking, then the broken solution will be preferred. I am still sorting out the finer details of this phenomenon in the Schwinger model, and a paper will be forthcoming. It remains to be seen whether the same effect will be present in the four-dimensional theories of interest.

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E. Kovacs. During the last half-year I have continued my work on the properties of the body-centered hypercubic(BCH) lattice and begun work on two new projects concerning the fermion doubling problem on the lattice and the nature of the QCD vacuum.

With collaborators W. Celmaster, F. Green and R. Gupta (Northeastern), I

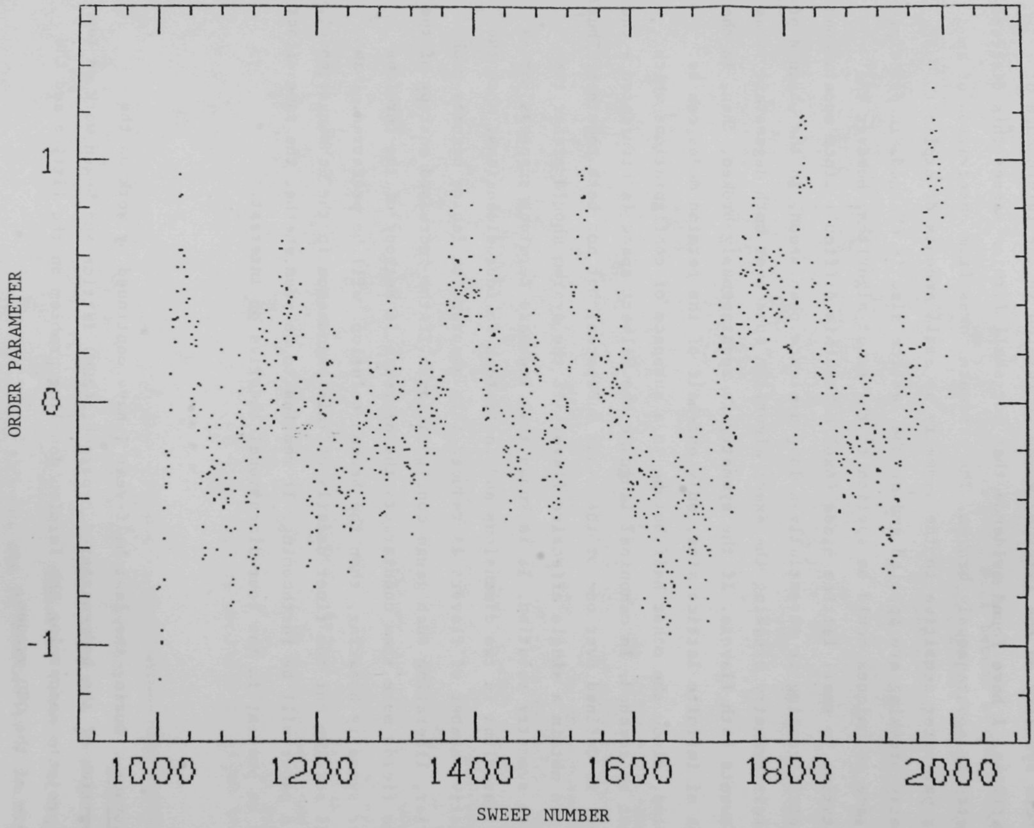

Fig. 10. A fermionic order parameter sensitive to the doubling symmetry is plotted vs. Monte Carlo time, for a run in which the gauge field is held fixed. A two-state behavior, characteristic of spontaneous symmetry breaking is observed, especially in the latter half of the run.

have completed the study of the deconfinement temperature on the BCH lattice. Our manuscript is currently in the final stages of preparation. Our study has shown that the deconfinement temperature, measured as a function of the critical coupling, exhibits significant violations of asymptotic scaling. Hence, the value of the ratio T_c/Λ_{BCH} extracted from the one loop fit to the data is not meaningful. Interestingly, the data appear to almost scale for a limited range of the inverse coupling, just as for the standard hypercubic lattice. However, as this coupling is increased, it appears that the data once again veer away from the asymptotic scaling curve. This suggests that perhaps the claims regarding the onset of asymptotic scaling in the hypercubic case are premature and need to be verified for larger values of the inverse coupling. One important feature of our study was the observation of very large finite volume effects in cases where the spatial size, N_s, of the lattice was only about 2 times the temporal size, N_t. Our study confirms that deconfinement temperatures should only be measured on lattices which have $N_s > 2.5\ N_t$. An analysis of the string tension data for the BCH lattice as a function of the coupling constant produces scaling violations that match those observed for the deconfinement transition for most of the coupling constant range considered. It remains unclear if the string tension data also veer away from their approach to asymptotic scaling. This needs to be studied in order to establish whether scaling, as opposed to asymptotic scaling, is valid.

Geoff Bodwin (Argonne) and I are attempting to provide a resolution of the controversy regarding the issue of fermion doubling in the so-called SLAC version of lattice field theory by contrasting the behavior of different lattice version of a specific model. We have chosen the lattice Schwinger model (2-d quantum electrodynamics) which, in the continuum, is completely soluble. We are in the process of calculating, in lattice perturbation theory with both Wilson fermions and SLAC derivatives, the mass of the lowest lying vector state and the axial vector anomaly. Both of these quantities are sensitive to the presence of fermion doubling. A comparison with the continuum results should provide a resolution of the fermion doubling issue for the SLAC derivative.

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H. Matsuoka. From April through September, my research mainly focused on the following two areas: exploring a new Monte Carlo renormalization group (MCRG) method and studying the QQQQ system in lattice QCD (in collaboration with Dennis Sivers).

The work on the MCRG was motivated by other MCRG studies of lattice QCD, which have provided a check for whether the asymptotic freedom scaling is respected in the coupling region where most current numerical simulations are done. The aim of this work, therefore, is to develop a more efficient and reliable MCRG method, which allows for a more systematic study of the scaling in lattice QCD. I have thus far tried the method on the two and three dimensional Ising models, for which I have obtained rather promising results. For the three dimensional Ising model, by using two lattices of 16^3 and 12^3, I have estimated the critical exponent, ν, for the correlation length to be ~0.63, which should be compared with the best available estimate of 0.629. Currently I am applying this method to the two dimensional XY model to calculate its β function before embarking on its application to the SU(2) or SU(3) lattice gauge theory.

In the work on the $Q\bar{Q}Q\bar{Q}$ system, we have been trying to understand the role of configuration mixing in the nuclear binding. In our paper entitled "Saturation of Color Forces and Nuclear Binding", submitted to Phys. Rev. D, we discuss the binding of two mesons composed of two heavy static quarks into a deuteron-like object. Presently we are setting up Monte Carlo simulations to see if we can detect the effect of configuration mixing numerically.

III. EXPERIMENTAL FACILITIES RESEARCH

A. Mechanical Support Activity

Proton Decay Experiment

The shop drawings of the structural steel crane and detector supports were checked and returned to C. Nelson & Assoc. Most of the locations for the utilities were resolved. Support details for the veto shield modules were approximately 80% complete.

The first shipment of equipment to be used in service and support activities for the Soudan 2 experiment left Argonne on a 40 ft flat bed truck. The load included machine tools, the 400 KUA power transformer and a five ton capacity surface fork lift. The logistics and shipping costs for the transporting of the five ton detector modules were addressed.

A final decision has been made to use the roof entry of forced air into the detector veto shield enclosure. Many small air ducts will be used to distribute air to various points inside the detector enclosure.

New methods were developed to correct problems experienced in aligning the modules during stacking. New fixtures were designed and are being built.

Fermilab Polarized Beam

The prototype snake magnet was disassembled, machined and reassembled. All of the magnets have been disassembled and the 24 coils to be reused have been tested and inspected. The core machining has begun. Design of the new pole pieces has been completed.

Testing of carbonized fabric for ground and high voltage planes of the large MWPC continued this quarter. A second "X" wire plane has been built to test ground and high voltage planes. In the next several months we will make a decision whether to use carbonized fabric, aluminized mylar, or wire.

E-704 Fermilab Polarized Proton Target

The ^3He pumping system received from Kinney Vacuum Corp. has been set up in Building 366, and is presently being tested. Some large components of the ^3He system have been leak tested, and defects are being corrected by the vendor. The ^3He gas system plumbing is under construction. Bases and supports for monitoring the ^3He equipment and magnet supports are being designed.

Wake Field Magnets

The designs of the quadrupole magnets were completed and the first 16 magnets have been ordered. Eight additional larger magnets are being designed and will be fabricated. Design work was begun on the bending magnets. (K. Coover)

B. Electronic Support

Support of the Soudan 2 Nucleon Decay Experiment continued to be a major effort during the quarter. Production of twelve data acquisition electronics crates for the experiment was begun. This is essentially half the data acquisition and compaction electronics which goes to the mine, and is enough to support approximately 500 tons of the detector. Three such crates were shipped to Oxford to support module testing in the U.K. module factory, and one to Minnesota for software development.

Considerable effort went into readying the U.K. preamp design for production of hybrids in the U.S. The order has been placed and we expect an initial prototype run of 50 hybrids (200 preamps) in late November. A test fixture for the hybrids is being built to utilize an IBM personal computer. After approval of the prototypes, the IBM personal computer and test fixture will be sent to the hybrid factory for production testing.

Production of the initial run of calibration cards and trigger communication cards continued, as did testing of the CMOS gate arrays which implement the trigger logic. (J. Dawson)

IV. ACCELERATOR RESEARCH AND DEVELOPMENT

A. Advanced Accelerator Test Facility

Plans for our Advanced Accelerator Test Facility are developing well. A major activity has been detailing the designs of the various beam transport sections of the facility. Figure 11 indicates the layout of these transports in the Bldg. 211 complex. We now summarize the design status by focussing on each section of the facility, beginning at the exit of the linac.

Linac-to-Target

The original design for this section used an existing 90 degree bending magnet to bend the beam away from the straight-through linac line. With that design, it was then necessary to use momentum-limiting slits to restrict the momentum spread to a small value. Still, five nanocoulombs were expected (per linac pulse) after the momentum selection. A complete redesign of this transport has been made using achromatic bends as shown in the figure. Simpler tuning and the possibility of transporting a full 15 nanocoulombs to the test facility will now be possible. The new design also leaves room for later installation of an rf cavity which can be used for pulse shaping. Both the increased pulse intensity and the capability of shaping the beam pulse are expected to play important roles in our experimental program. As indicated in the figure, provisions have also been made to permit simple switching of the beam between our facility and the experimental area to be used by radiation chemists.

Pulse Forming Sections

Constrained by several simultaneous demanding requirements, this section has required considerable design effort. Both legs of the section must be achromatic, isochronous, and of such lengths that the

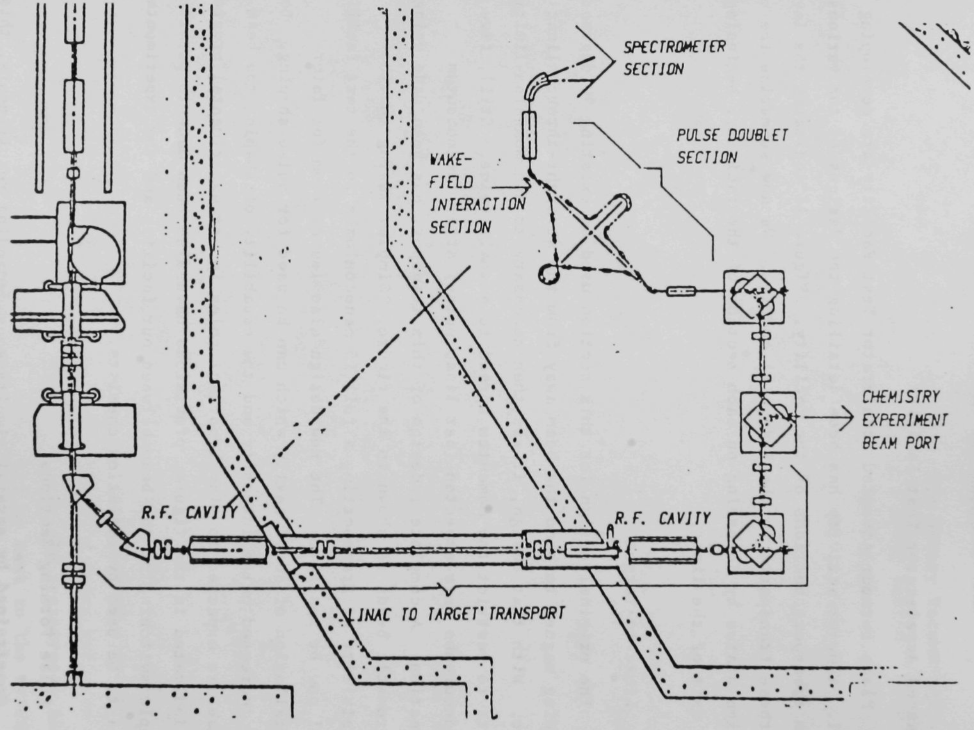

Fig. 11. Layout of the Advanced Accelerator Test Facility in Bldg. 211.

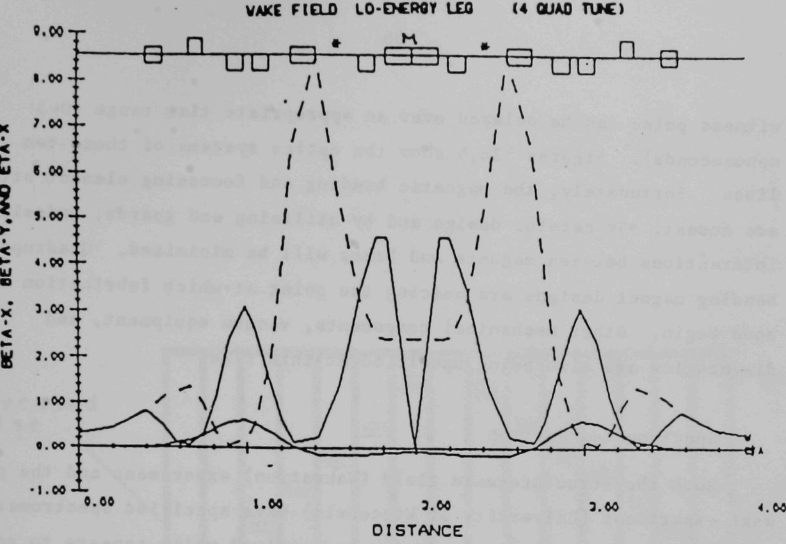

Fig. 12a. Beam optics of the low energy leg. The length of this line is adjustable by moving bend magnet, M, plus its adjacent quadrupoles. This changes the length of straight sections, *. The total length can vary by one meter.

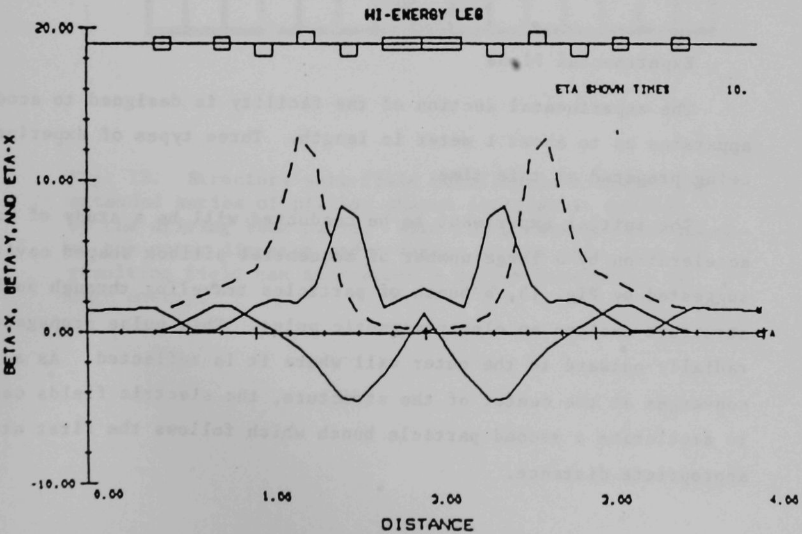

Fig. 12b. Beam Optics of the High Energy Leg.

witness pulse can be delayed over an appropriate time range (0-3 nanoseconds). Figures 12a,b show the optics systems of these two lines. Fortunately, the magnetic bending and focussing element strengths are modest. By careful design and by utilizing end guards, undesirable interactions between magnets and beams will be minimized. Quadrupole and bending magnet designs are nearing the point at which fabrication will soon begin. Other mechanical components, vacuum equipment, and diagnostics are also being specified at this time.

Spectrometer Section

Both the structure wake field (Wakeatron) experiment and the plasma wake experiment (University of Wisconsin) have specified spectrometer requirements. A preliminary design has evolved which appears to satisfy the needs of both experiments. It uses a 45 degree exit angle, 90 degree bend for each energy beam. With a 1.1 meter bending radius for the high energy beam, the spectrometer magnet will be the largest single magnet in the system. However, because its field strength need be only 700 Gauss, the magnet will still be a "toy" by most HEP standards.

Experimental Plans

The experimental section of the facility is designed to accommodate apparatus up to about 1 meter in length. Three types of experiments are being prepared at this time.

The initial experiment to be conducted will be a study of wake field acceleration by a large number of sequential pillbox shaped cavities. As suggested by Fig. 13, a bunch of particles traveling through such a structure excites an electromagnetic pulse. This pulse propagates radially outward to the outer wall where it is reflected. As a pulse converges at the center of the structure, the electric fields can be used to accelerate a second particle bunch which follows the first at an appropriate distance.

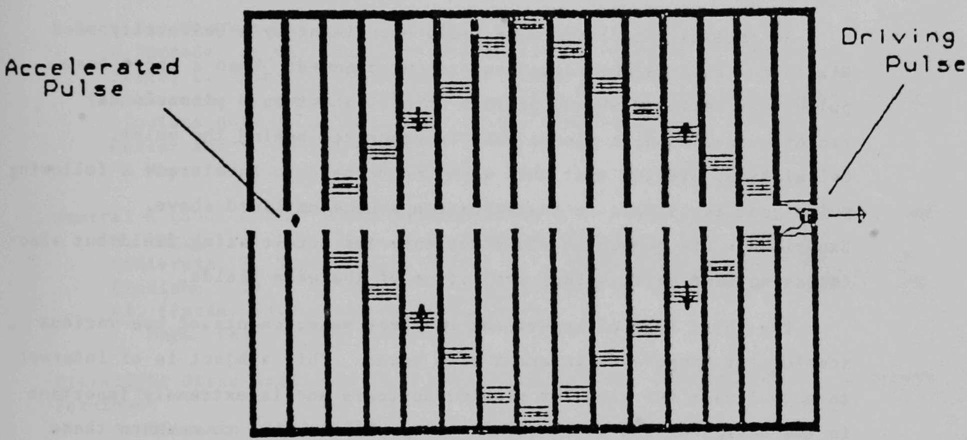

Fig. 13. Structure wake field accelerator concept. An extended series of pillbox shaped cavities is excited by the driving beam pulse. When the pulses are reflected at the outer diameter and coverage at the axis, the resulting field can accelerate a second beam pulse to high energy.

There have been both analytic and numerical studies of the geometric dependencies, yet no experimental verification of such studies have been made. The attractive feature of such an accelerating scheme is that existing proton beams, such as are available at FNAL, might be used to generate electron beams in excess of 1 TeV. Experiments such as those planned for our facility are essential for designing future experiments with protons.

An interesting plasma wake field experiment by a University of Wisconsin group is the second experiment planned. When a short beam pulse (our facility should provide them as short as 6 picoseconds) traverses a plasma, a plasma wake is generated behind the pulse. Calculations predict that this wake can be used to accelerate a following pulse just as is done in the Wakeatron scheme outlined above. Experiments are needed to study not only the accelerating field but also focussing (and defocussing) properties of the wake fields.

The third type of experiment involves measurements of how various accelerator components interact with beams. This subject is of interest to both linear and circular machine builders and is extremely important in the design of the SSC. Our facility will be able to measure these interactions (parameterized as longitudinal and transverse impedances) for accelerator hardware such as beam pipes and diagnostic equipment.

Schedule

A formal proposal has been submitted to DOE for incremental funding to enable completion of this project in a timely, competitive manner. With this support, the facility will begin test by summer of 1986. Actual hardware installation of upstream beam transport elements is scheduled to begin in January, 1986.

V. PUBLICATIONS

A. Journal Publications, Conference Proceedings, Books

Measurement of the Topological Branching Fraction of the τ Lepton
M. Derrick, E. Fernandez, R. Fries, L. Hyman, P. Kooijman, J.S. Loos, B. Musgrave, L.E. Price, J. Schlereth, K. Sugano, J.M. Weiss, D. E. Wood (ANL), G. Baranko, et al. (Indiana Univ.), C. Akerlof, et al. (Univ. of Michigan), I. Beltrami, et al (Purdue Univ.)
Phys. Rev. Lett. 55, 570 (1985)

Search for New Neutral Particles in e^+e^- Annihilations at 29 GeV
D. Errede, et al. (Univ. of Michigan); M. Derrick, E. Fernandez, R. Fries, L. Hyman, P. Kooijman, J.S. Loos, B. Musgrave, L.E. Price, J. Schlereth, K. Sugano, J.M. Weiss, and D.E. Wood (ANL); S. Ahlen, et al. (Indiana Univ.); I. Beltrami, et al. (Purdue Univ.); B Cork (LBL); L. Keller and J. Va'vra (SLAC).
Phys. Lett. 149B, 519 (1985)

Neutral $K^*(890)$ and ρ^o Meson Production in e^+e^- Annihilation at $\sqrt{s}$ = 29 GeV
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Phys. Lett. 158B, 519 (1985)

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J. Oliensis (ANL), C. Albright (Fermilab/Northern Ill. Univ.)
Phys. Lett. 160B, 121, (1985)

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K. F. Johnson (ANL), H. Burkard et al. (Institut fur Mittelenergiephysik, Switzerland), J. Egger et al. (Schweizeisches Institut fur Nuklearforschung, Switzerland), F. Scheck (Johannes-Gutenberg Universitat, Federal Republic of Germany)
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Phys. Lett. 161B, 79 (1985)

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R. Tucci (ANL)
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E.L. Berger (ANL)
Phys. Rev. D32, 1071 (1985)

A Fast Algorithm for Monte Carlo Simulations of Systems with Fermions
M. Grady (ANL)
Phys. Rev. D32, 1496 (1985)

Measurements of Triple- and Double-Spin Parameters in Elastic p-p Scattering at 6 GeV/c
I.P. Auer, J. Chalmers, E. Colton, R. Giese, H. Halpern, D. Hill, R. Miller, K. Nield, B. Sandler, H. Spinka, N. Tamura, D. Underwood, Y. Watanabe, A. Yokosawa (ANL), A. Beretvas, D. Miller (Northwestern Univ.)
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D. Ayres, J. Dawson, T. Fields, E. May, L. Price and K. Sivaprasad (ANL), J. Bartelt, et al. (Univ. of Minnesota)
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Parallel Computing, 2, 137 (1985)

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R. Hagstrom, G. Bolotin, and J. Dawson (ANL)
Proceedings of the Argonne National Laboratory Workshop on Gauge Theory on a Lattice: 1984, edited by: C. Zachos, W. Celmaster, E. Kovacs, and D. Sivers, 27, (1984)

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J.M. Weiss (ANL)
23rd International Conference on High Energy Physics, Leipzig, E. Germany, July 18-25, 1984, Vol. 1, 316 (1985)

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J. Dawson, E.N. May, and N. Solomey (ANL)
IEEE 1984 Nuclear Science Symposium, Orlando, FL, Oct. 31-Nov. 2, 1984, NS-32, No. 1, 221 (1985)

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Ibid., 711 (1985)

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Performance of the CDF Central Electromagnetic Calorimetry
P. Schoessow, R. Diebold, L. Nodulman et al. (ANL), V. Barnes et al., (Purdue Univ.)
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M. Derrick (ANL)
Proceedings of the Workshop on e^+e^- Physics at High Luminosities, Stanford Linear Accelerator Center, Stanford, CA, April 5-7, 1985, SLAC-283, 208 (1985)

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B. Papers Submitted for Publication and ANL Reports

Inclusive Charged Particle Production Near the Kinematic Limit in e^+e^- Annihilation at 29 GeV

M. Derrick, P. Kooijman, J.S. Loos, B. Musgrave, L.E.Price, J. Schlereth, K. Sugano, J.M. Weiss, D.E. Wood (ANL); P. Baringer, et al. (Indiana Univ.); C. Akerlof, et al. (univ. of Michigan); S. Abachi, et al. (Purdue Univ.) ANL-HEP-PR-85-77

Phys. Lett.

On the Fermion Mass and Lattice Size Dependence of SU(2) Gauge Theory Thermodynamics

D. Sinclair (ANL); J. Kogut, J. Polonyi et al. (Univ. of Illinois Urbana); J. Shigemitsu (Ohio State Univ.) ANL-HEP-PR-85-78

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D. Sinclair (ANL); J. Kogut, J. Polonyi et al. (Univ. of Illinois, Urbana) ANL-HEP-PR-85-79

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D. Sivers, H. Matsouka (ANL) ANL-HEP-PR-85-89

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A.White, C. Willcox (ANL), E. Braaten (Northwestern Univ.) ANL-HEP-PR-85-90

Phys. Rev. D

QCD Corrections to Polarized Σ^- Beta Decay: Second Class Form Factor Effects

L. Carson, R. Oakes, C. Willcox (ANL/Northwestern U.) ANL-HEP-PR-85-91

Phys. Lett. B

The Two Particle Inclusive Cross Section in e^+e^- Annihilation at Petra, PEP and LEP Energies
J. Collins (ANL/IIT) ANL-HEP-PR-85-92
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Induced Second-Class Form Factors in Σ^- β-Decay
L.J. Carson, R. J. Oakes, C.R. Willcox (ANL/Northwestern Univ.)
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Dynamical Symmetry Breaking by Radiative Corrections in a Left-Right Higgs Model
J. Oliensis (ANL) ANL-HEP-PR-85-101
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Nuclear Effects in Massive Lepton Pair Production
E.L. Berger (ANL) ANL-HEP-PR-85-102
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Test Facility for Advanced Acceleration Methods
J. Simpson, J. Norem, A. Ruggiero (ANL) ANL-HEP-TR-85-54
Technical Note

Accelerator Technology for Space Application
A.G. Ruggiero (ANL) ANL-HEP-TR-85-55
Technical Note

A State-of-the-Art 1-2 GeV Synchrotron Radiation Source: Options for Upgrading Aladdin
Y. Cho (ANL) ANL-HEP-TR-85-76
Technical Note

Search for Experimental Proof of the Existence of Lower Components in the Nuclear Wave Function
D. Hill (ANL); G.W. Hoffmann, et al. (LANL); G. Burleson, G. Kyle et al. (New Mexico State Univ.); N. Hintz, et al. (Minnesota); B.C. Clark (Ohio State); R.L. Bercer, (IBM); R. W. Fergerson, C. Glashausser (Rutgers)
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Los Alamos Meson Physics Facility Proposal

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Los Alamos Meson Physics Facility Proposal

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K. Johnson, I. Ohashi, H. Spinka (ANL), T.S. Bhatia, et al. (Texas A&M Univ.), D. Fitzgerald et al. (Los Alamos National Laboratory), G. Burleson et al. (New Mexico State Univ.), R.H. Jeppesen (Univ. of Montana), G.E. Tripard (Washington State Univ.) ANL-HEP-TR-85-87
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M. Derrick for Group. ANL-HEP-TR-85-95
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D. Hill, K. Johnson, I. Ohashi, T. Shima, H. Spinka, R. Stanek, D. Underwood, A. Yokosawa (ANL), T.S. Bhatia, et al. (Texas A&M Univ.), J. J. Jarmer (Los Alamos National Laboratory), G. Burleson et al. (New Mexico State Univ.), G.E. Tripard (Washington State Univ.) ANL-HEP-TR-85-96
Los Alamos Meson Physics Facility Proposal

Comment on an Unusual Event in the E594 Detector from the Direction of Cygnus X-3
M. Goodman (ANL) ANL-HEP-TR-85-97
Technical Note

C. Papers or Abstracts Contributed to Conferences

Left-Right Symmetric Model with Ultralight Dirac Neutrinos
J. Oliensis (ANL) ANL-HEP-CP-85-62
Photon-Lepton Conference, Kyoto, Japan, August 19-24, 1985

New Results on Bhabha Scattering at 29 GeV
J.S. Loos and D.E. Wood (ANL) ANL-HEP-CP-85-80
1985 Annual Meeting of the APS Division of Particles & Fields, Univ. of Oregon, Eugene, Oregon (Aug. 12-15, 1985) and 1985 Intl. Conference on Lepton-Photon Interactions at High Energies, Kyoto, Japan, August 19-24, 1985

Heavy Particle Production in High Energy Hadron Collisions
J. Collins (ANL), D. Soper (Univ. of Oregon), G. Sterman (ITP, Stony Brook) ANL-HEP-CP-85-68
Oregon Workshop on Super High Energy Physics, Univ. of Oregon, Eugene, Oregon, March 18-August 10, 1985

Torsion and Geometrostasis in Covariant Superstrings
C. Zachos (ANL) ANL-HEP-CP-85-106
1985 Annual Meeting of the APS Division of Particles & Fields, Univ. of Oregion, Eugene, Oregon, August 12-15, 1985

np Eleastic-Scattering Experiments with Polarized Neutron Beams
J.S. Chalmers, W.R. Ditzler, D. Hill, J. Hoftiezer, K. Johnson, T. Shima, H. Shimizu, H. Spinka, R. Stanek, D. Underwood, R. Wagner, A. Yokosawa (ANL); T.S. Bhatia, et al. (Texas A&M Univ.); R. Damjanovich, et al. (Los Alamos National Laboratory); G. Burleson, et al. (New Mexico State Univ.); R.H. Jeppesen (Univ. of Montana); G.E. Tripard (Washington State Univ.) ANL-HEP-CP-85-83
6th International Symposium on Polarization Phenomena in Nuclear Physics, Osaka University, Osaka, Japan, August 26-30, 1985

Polarization Phenomena in Nucleon-Nucleon Scattering at Intermediate and High Energies Including the Present Status of Dibaryons
A. Yokosawa (ANL) ANL-HEP-CP-85-93
Ibid.

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D. Sivers (ANL) ANL-HEP-CP-85-94
Nuclear Chromodynamics Conference, Institute for Theoretical Physics, Santa Barbara, California, August 12-23, 1985

Evidence from the Soudan 1 Experiment for Underground Muons Associated with Cygnus X-3.
D.S. Ayres (ANL) ANL-HEP-CP-85-100
19th International Cosmic Ray Conference, Univ. of California, LaJolla, CA, August 11-23, 1985

Structure Functions of Nuclei in the Pion Exchange Model
E.L. Berger, F. Coester (ANL) ANL-HEP-CP-85-103
Santa Barbara Workshop on Nuclear Chromodynamics, Santa Barbara, CA, August 12-23, 1985

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H.J. Lipkin (ANL) ANL-HEP-CP-85-107
Ibid.

Diffraction Scattering and the Parton Model in QCD
A. White (ANL) ANL-HEP-CP-85-104
Workshop on Elastic and Diffractive Scattering at the Collider and Beyond, Blois, France, June 3-6, 1985

D. Technical Notes

HRS-338	Study of the Mean Charged Particle Multiplicity of Gluon Jets Produced in e^+e^- Annihilation at 29 GeV K. Sugano
LS-27	The Effect of the Residual Gas on the Beam Life Time in Electron (Positron) Storage Ring T. K. Khoe
LS-28	Folded Coaxial Line Design for the 38.9 MHz Booster Cavity R. L. Kustom
LS-29	Nonideal Undulator Spectra S. H. Kim
LS-30	POISSON Codes Available on ANLHEP S. L. Kramer
LS-31	Parameter Sheets for a 6-GeV Storage Ring Model Y. Cho, H. Moe, E. Crosbie, J. Moenich, T. Khoe, W. Praeg, S. Kim, G. Shenoy, M. Knott, L. Teng, S. Kramer, K. Thompson, R. Kustom, R. Wehrle, D. McGhee
LS-33	Multipactoring in a Positron Storage Ring T. K. Khoe
PDK-212	Monopole Flux Limits from Soudan-1 J. Bartelt, H. Courant, K. Heller, T. Joyce, M. Marshak, E. Peterson, K. Ruddick, M. Shupe, D. Ayres, J. Dawson, T. Fields, E. May and L. Price
PDK-213	Coordinates, Numbering Schemes, Connectors and Names for Soudan-2 G. Pearce, E. Peterson, and J. Hoftiezer
PDK-214	Estimated Cosmic Ray Event Rates in Soudan 2 Including Universal Sources M. Goodman
PDK-218	Soudan 2 Nucleon Decay Experiment Quarterly Activity Report April-June 1985 D. Ayres
PDK-223	The Soudan 2 "Multiplexing" Scheme J. Thron

VI. PUBLICATIONS BASED ON ZGS EXPERIMENTS

The following paper reporting the results of a ZGS experiment was published this quarter.

Experiment	Publication
E-401: Measurement of Observables (N,S;O,S), (O,S;OS), and (N,O;O,N) at 6 GeV/c. Northwestern University and Argonne National Laboratory	Measurements of Triple-and Double-Spin Parameters in Elastic p-p Scattering at 6 GeV/c. I.P. Auer, et al., Phys. Rev. D32, 1609 (1985).

VII. COLLOQUIA AND CONFERENCE TALKS

D. Ayres

"Evidence from the Soudan 1 Experiment for Underground Muons Associated with Cygnus X-32"
19th International Cosmic Ray Conference, LaJolla, CA (August 1985)

F. Cole

"Longitudinal Motion in Accelerators"
Lectures given at SLAC (July 1985)

J. Collins

"QCD Results for Small x and for Heavy Flavor Production"
Conference on Super-High-Energy Physics, Eugene, OR (August 1985)

"The States of Perturbative QCD"
DPF Meeting of the APS, Eugene, OR (August 1985)

"Heavy Flavor Production"
University of Wisconsin, Madison, WI (September 1985)

M. Goodman

"Cosmic Ray Physics at 5000 TeV"
Illinois Institute of Technology (September 1985)

H. Matsuoka

"Macroscopic Renormalization Group"
Schlumberger-Doll Research, CT (July 1985)

E. May

"An Observation of Muons from Cygnus X-3 in the Underground Soudan 1 Detector"
Gordon Conference on Particle Physics (August 1985)

L. Price

"High Energy Muons from Astrophysical Sources"
DPF Meeting of the APS, Eugene, OR (August 1985)

"New Physics from Cygnus X-3?"
University of Florida, Gainesville, FL (September 1985)

A. Ruggiero

"New Methods of Acceleration"
Case Western Reserve University, Cleveland, OH (September 1985)

D. Sivers

"Color Force Saturation and Nuclear Binding"
Workshop on Nuclear Chromodynamic, Santa Barabara, CA (August 1985)

A. Yokosawa

"Polarization Phenomena in Nucleon-Nucleon Scattering at Intermediate and High Energies Including the Present Status of Dibaryons"
6th International Symposium on Polarization Phenomena in Nuclear Physics, Osaka, Japan (August 1985)

C. Zachos

"Geometrostasis and Torsion in Covariant Superstrings"
DPF Meeting of the APS, Eugene, OR (August 1985)

"σ-models and Superstrings"
Lectures given at Cinvestav of the National Polytechnic Institute of Mexico (August 1985)

VIII. HIGH ENERGY PHYSICS RESEARCH PERSONNEL

Accelerator Physicists

Y. Cho	J. Norem
F. Cole	A. Ruggiero
E. Crosbie	J. Simpson
T. Khoe	L. Teng
S. Kramer	G. Wustefeld

Experimental Physicists

D. Ayres	Y. Ohashi
M. Derrick	L. Price
R. Diebold	J. Proudfoot
T. Fields	M. Rushton
M. Goodman	P. Schoessow
R. Hagstrom	T. Shima
J. Hoftiezer	H. Shimizu
K. Johnson	H. Spinka
P. Kooijman	R. Stanek
W. Li	K. Sugano
J. Loos	J. Thron
E. May	D. Underwood
N. Mondal	R. Wagner
B. Musgrave	A. B. Wicklund
L. Nodulman	A. Yokosawa

Theoretical Physicists

E. Berger	D. Sinclair
G. Bodwin	D. Sivers
J. Collins	W. K. Tung
W. Grady	A. White
E. Kovacs	C. Zachos
H. Matsuoka	

Engineers, Computer Scientists and Applied Scientists

J. Clausing	N. Hill
K. Coover	R. Kustom
J. Dawson	J. Schlereth
D. Hill	D. Suddeth

Technical Support Staff

I. Ambats	T. Kasprzyk
L. Balka	R. Konecny
J. Biggs	R. Laird
H. Blair	R. Miller
W. Evans	R. Rezmer
W. Haberichter	J. Sheppard
D. Jankowski	E. Walschon